THE RELATIVE IMPORTANCE OF THE AEROBIC ANAEROBIC AND EFFICIENCY COMPONENTS TO A ONE MINUTE MAXIMUM PERFORMANCE

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ABSTRACT

This study was done to determine the relationship of the following factors;

(1) Anaerobic component

(2) Efficiency component

and (3) Aerobic component

to a one minute maximum performance.

The sample (N = 20) was subjected to two tests, a maximum oxygen consumption test and a one minute maximum performance (MMP) test. In addition to these tests, age, height, weight and percentage body fat were obtained.

All oxygen consumption and work values were expressed as ml. and Kgm respectively per Kg of body weight. Efficiency was defined as work done in Kgm/ml oxygen consumed.

Spearman's rank correlation coefficients and t-tests for paired samples were employed in the statistical analysis of the data. Significant correlations (at .01 level) were obtained for the relationships of oxygen debt and anaerobic work to the one minute maximum performance. Significant differences were found between aerobic and anaerobic work and between aerobic and anerobic efficiency.

It was concluded that, (1) oxygen debt tends toward a positive relationship with MMP; (2) anaerobic work has a positive linear relationship with MMP; (3) ability to work anaerobically is more important to attaining a high MMP than ability to work aerobically; (4) Aerobic efficiency

during MMP is significantly higher (.05 level) than anaerobic efficiency; and (5) all of the components - aerobic, anaerobic and efficiency, make some contribution to the MMP.

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Chapter 1

INTRODUCTION

Statement of problem:

Despite the great strides in exercise physiology and related areas, there remains a large void in the knowledge of man's ability to perform. One area in which knowledge is lacking is that of one minute maximum performance.

When studying this topic the following question arises; What is the relative importance of each of the components,

(1) anaerobic

(2) efficiency

and (3) aerobic

to a maximum one minute performance?

There have been numerous studies of the various aspects of aerobic metabolism, anaerobic metabolism and efficiency. However, the relationship of these factors to one minute maximum performance has, until now, been dealt with less. The literature does refer to "all-out" (Nagle 1963) runs which took up to thirteen minutes to attain. There is no doubt that exhaustion occurred, but the phrase, "all-out", implies maximum effort from beginning to end. The duration of the work, not the intensity, was the factor most likely to have resulted in exhaustion, due to depletion of the muscles' energy stores. According to Magaria (et al 1964) an athlete running all-out is unable to continue for more than forty seconds. This forty second limit was also observed by the experimenter during a laboratory session in which physical education students were told to ride a bicycle ergometer as fast and as long as they could.

It is common knowledge that at the beginning of exercise, the body's cardio-respiratory system experiences a lag, causing an oxygen deficit which must be repaid at the end of exercise as the oxygen debt. Although a study by Lukin (1963) reports a repayment to deficit ratio from .6 to 3.6 for mild to intense exercise, it is generally held that the two approximately cancel each other out. Other studies, one by Henry (1954) demonstrate the possibility of estimating total oxygen requirements for given performances and another by Cunningham (1966) indicated a positive linear relationship between excess lactic acid and oxygen debt.

Such studies as the above, although they provide for a greater understanding of aerobic and anaerobic metabolism, do not describe their relationship in terms of a one minute maximum performance.

Purpose:

The purpose of this investigation was to determine the relative importance of each of the following:

(1) Anaerobic component

(2) Efficiency component

and (3) Aerobic component,

to a one minute maximum performance.

Significance of Study:

An extensive discussion of aerobic and anerobic metabolism and efficiency may be found in any textbook of exercise physiology. The relationship of these factors to a one minute maximum performance, however, did not appear in the review of literature. The awareness of the relationships of the components to one minute maximum performance is of obvious importance to sprinting events of approximately one minute duration as in swimming and track. Less obvious is the value of such knowledge to hockey, basketball, wrestling, gymnastics and many other sports, where competitors are often required to drive as hard as they can for one minute. An improvement in one minute maximum performance would result in improved athletic performance.

Hypothesis:

It was hypothesized that there are no correlations between aerobic metabolism, anaerobic metabolism, and efficiency, on the one hand and one minute maximum performance on the other.

Limitations:

(1) Work done as a result of increased respiratory and circulatory activity during recovery may have resulted in an overestimate of oxygen debt. As can be seen in fig. 1, oxygen debt is greater than the oxygen deficit. This difference is thought to be the result of several factors;

(a) gluconeogenesis

(b) restoration of electrolyte balance

(c) cooling of the elevated body temperature

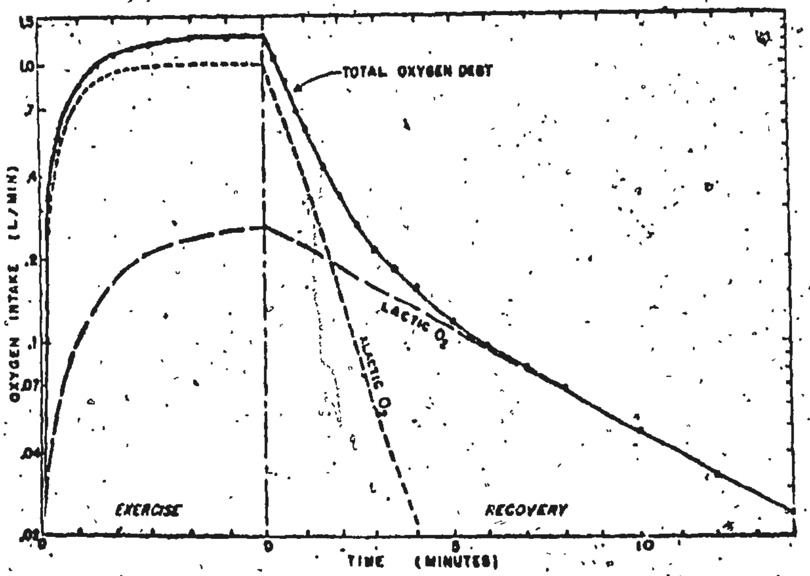

Figure 1

Oxygen Consumption During Exercise
and Recovery

*Adapted from Karpovich and Sinning, Physiology of Muscular Activity, p. 96.

through circulatory activity.

and (d) increased adrenalin level, which causes an increase in oxygen utilization but decreases the efficiency of this usage.

(Morehouse and Miller 1971)

(2) Maintaining resting position (fig. 2) during recovery, which took from 11 to 27 minutes, may have caused fatigue of postural muscles thus increasing oxygen consumption. For a given workload fatigued muscles demand more oxygen than rested muscles (Clarke 1957).

(3) Anxiety prior to testing could have created an increase in resting heart rate of the subjects. If this state of anxiety was not also present during recovery then an underestimate of oxygen debt may have occurred, since heart rate was the criterion for determining recovery time. Antel and Cumming (1969), when studying the effect of emotional stimulation on exercise heart rate, found that the effects of emotion are not blocked during exercise. They did not indicate, however, whether or not pre-exercise emotions had any influence on recovery.

(4) Some subjects may not have yielded a maximum effort due to, (a) lack of incentive or willingness to perform, (b) driving too hard during first half of the test, resulting in ~~a~~ limited performance due to lactate formation, or (c) not working sufficiently for the first thirty seconds.

(5) In running, oxygen cost does not rise linearly with velocity but with the square of velocity (Knuttgen and Ralston 1952). Because of the resulting decrease in efficiency aerobic work done may have been overestimated.

Figure 2

Resting Position on Experimental Apparatus

The aerobic work done during the one minute maximum performance was based on the subject's efficiency in the maximum oxygen intake test. For example, if the oxygen consumption during the one minute maximum performance was 75 % of the maximal oxygen consumption and the physical working capacity was 1000 Kgm (arbitrary value), then the aerobic work done in the maximum performance test was 750 Kgm.

(6) Efficiency of anaerobic work may have been slightly inaccurate as a result of :

(a) changes in respiratory quotient during and after work - with intense work R.Q. may approximate 1 whereas during recovery R.Q. may be as high as 1.5 or as low as 0.7. (Karpovich and Sinning 1971).

(b) Metabolic rate can be elevated above normal as long as eight hours after exercise. (Gray and DeVries 1963). Whether or not this prolonged elevation is an aftereffect of exercise (Biochemical change) or a continued repayment of oxygen deficit is not agreed upon.

(7) Proficiency on the experimental apparatus does not indicate proficiency in other activities. In the case of swimmers, for instance, the stretch reflex may play an inhibitory role due to the greater degree of flexion in the knee and hip joints. The extensors of these joints were thus stretched to a length uncommon in these subjects.

Definitions:

One minute Maximum Performance - the maximum amount of work the subject was able to do on the experimental apparatus fig. 3 page 10. The work included both aerobic and anaerobic work.

Aerobic component - consisted of the work done in Kgm and which can be accounted for by the VO_2 consumed during one minute maximum efforts.

Anaerobic component - consisted of the work done anaerobically and the oxygen debt incurred. Oxygen debt included the lactacid and alactacid and the increased oxygen utilization due to the factors described in limitation 1 page 3.

Efficiency - consisted of both aerobic and anaerobic and due to the nature of determination was expressed as Kgm/ml of oxygen.

Chapter 2

METHODOLOGY

Research design:

The subjects were given two tests (1) a maximum oxygen consumption test (VO_2 max) and (2) a one minute maximum performance test, with the first being done on one day and the latter not less than two days later. In both tests the subjects were required to drive an apparatus (fig. 3) consisting of two bicycle ergometers so arranged as to be pedalled with both arms and legs. The reason for such an arrangement being to ensure that fatigue was the result of depletion of aerobic and anaerobic resources.

On the first day, in addition to administering the VO_2 max test, age, height and weight were recorded and skinfold measurements were obtained using Harpenden skinfold calipers.

Sample:

The sample (N=20) was chosen on the basis of two main criteria, (1) availability and (2) activity level. Activity level was considered one of the criteria because of the nature in which the testing was done - VO_2 max was measured directly, not estimated from a submaximal workload. Such an effort by inactive subjects might have proven harmful. The sample was discriminatory in that all subjects were males. The all male sample was a deliberate measure to avoid any influence the variable, sex, might have had. The subjects ranged from

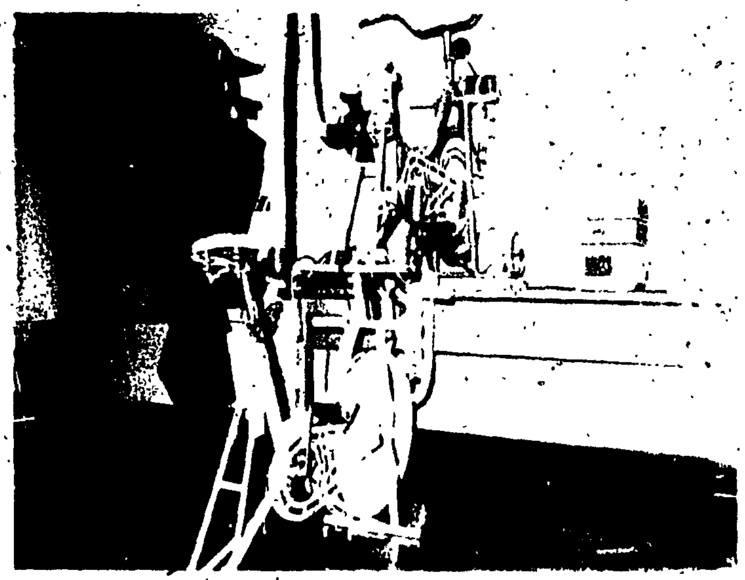

Figure 3

Double Bicycle Braking Apparatus

individuals who followed irregular patterns of activity to very highly conditioned competitors. Means and ranges for age, height, weight and percentage body fat follow:

Variable	Mean	Range
Age	21.65 yr.	15-26
Height	174.63 cm.	60-73
Weight	71.97 kg.	60.45 - 98.41
% Fat	4.48	2.55 - 6.47

Procedure:

Prior to administering the VO_2 max test the age, height and weight of each subject was recorded. Subjects weighed in the nude and height was measured in bare feet with subject standing straight.

In addition to the above anthropometric measures skinfold measurements were also obtained. Abdominal, chest and arm skinfolds were measured using a Harpenden calipers (fig. 4, 5, 6). Brozek and Keys' formula for estimating specific gravity was employed

$$\text{Specific gravity} = 1.1017 - 0.00028A - 0.000736B - 0.000883C$$

Where A = abdominal skinfold. mm
B = chest skinfold. mm
C = arm skinfold. mm

and the resulting value used to determine the percent body fat from table 7 page 39.

The VO_2 max test was then conducted in the following manner:

Electrodes were attached at the forehead, upper portion of sterum and lower portion of sterum to offer the least interference from neuromuscular activity. Heart rate was

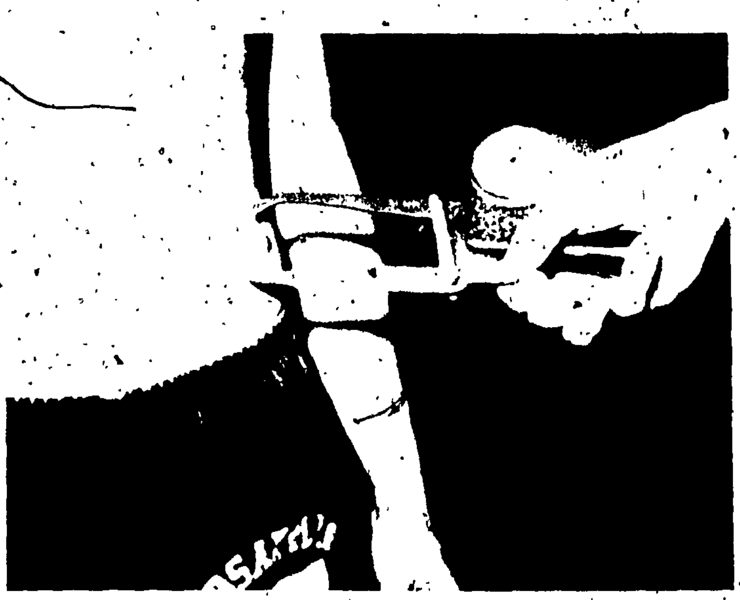

Figure 4. Abdominal Skinfold

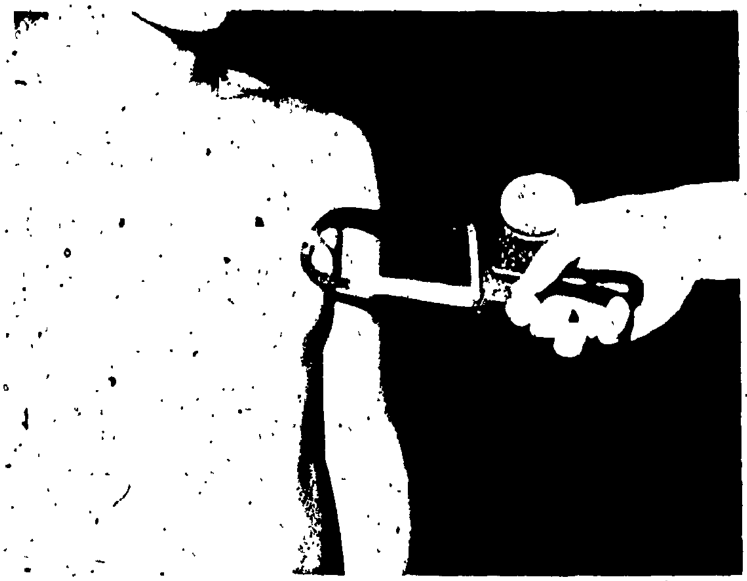

Figure 5. Chest Skinfold

Figure 6. Arm Skinfold

recorded via telemeter on a Hewlett Packard heart rate counter.

The pedals and seat were adjusted so that the arms and legs could be fully extended. The Gas mask (fig. 8 p. 21), though not ideal, was raised or lowered to afford maximum comfort within the limits of the apparatus.

Subjects breathed through a low resistance gas mask with attached rubber mouthpiece. The use of a nose plug prevented any loss of air. On each testing the gas mask and nose plug were checked for leakage.

The apparatus having been made as comfortable as possible, the subject commenced pedalling the apparatus at approximately 60 rpm. Tension was increased intermittently, allowing one minute for circulo-respiratory adjustment. The ratio of arm tension to leg tension was approximately 1:3.

As the subjects' heart rate approached 170 one and a half minutes were allowed for adjustment to the workload. When the 170 heart rate was reached the first of a series of one minute expired air collections was taken. At the end of each collection the subject was encouraged to continue, the tension was increased, one and a half minutes were allowed for adjustment to new workload, heart rate was recorded, and expired air was collected for one minute. The range in time to reach a maximum workload was eight to thirteen minutes.

Rubberized Douglas bags were used to collect expired air during each one minute collection. The bags were arranged as in figure 7 connected with rubber tubing and two way valves. The two way valves allowed control of the direction of air flow.

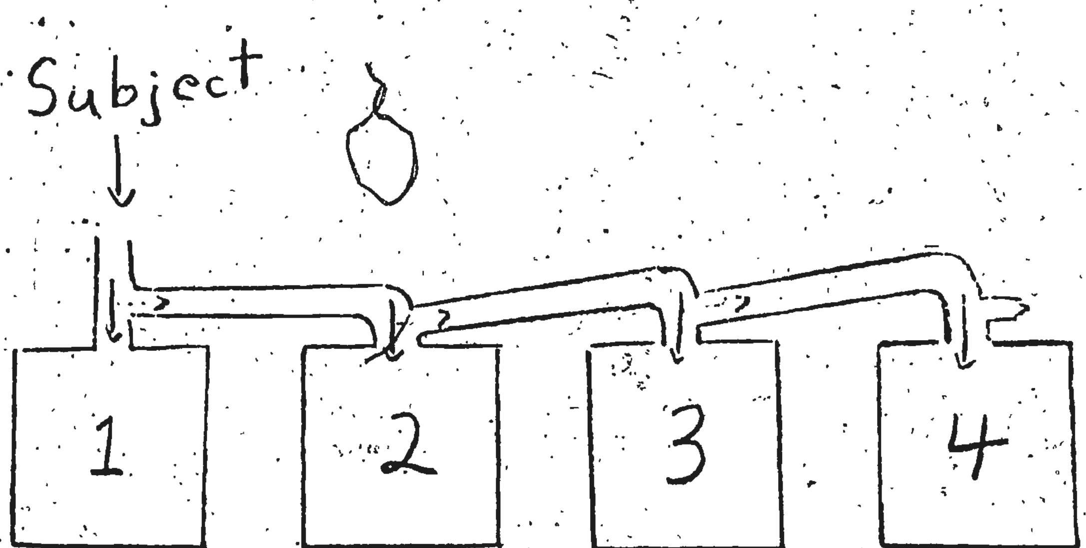

Figure 7

Douglas Bag Arrangement

Each bag was shaken to thoroughly mix the expired air and the volume measured by passing it through a dry spirometer. Samples were taken at the beginning and when the bag was almost completely emptied. The sample volume (150 ml) was added to the bag volume. Each sample was run through a Rapox gas analzyer to determine percentage difference in oxygen.

Room temperature and barometric pressure were recorded. The volumes obtained were converted to STPD, using formula in table 1, and multiplied by the percentage difference in oxygen to determine volume of oxygen consumed. The highest value obtained for each subject was used as $\dot{V}O_2$ max.

In the one minute maximum performance test the apparatus used was the same as for the $\dot{V}O_2$ max test. This test consisted of (1) a five minute resting volume to determine resting metabolic rate, (2) a one minute maximum performance and (3) recovery.

The subjects were required to sit on the apparatus and breathe through the low resistance mask for six minutes. In order to allow a more accurate measurement of resting metabolic rate the first minute was used merely for practice - earlier observation indicated that subjects' tidal volumes tended to decrease thus increasing respiratory work. At the beginning of the second minute the expired air was directed into bag 1 (fig. 7, p. 16) by means of the two way valve. The bag was closed at the end of the sixth minute. The subject was then allowed to remove the gas mask and dismount the apparatus. Resting heart rate was recorded at approximately the five minute mark. The resting gas volume was immediately measured and the percentage difference in oxygen recorded.

Table 1. Formula for Conversion at Measured Volumes to STPD

$$V_1 = V_0 \times \frac{T_1}{T_0} \times \frac{P_0}{P_1 - P_2}$$

V_1 = Vol. corrected to STPD

V_o = Measured volume

T_1 = 273° K

T_o = Room Temperature

P_1 = Standard pressure

P_o = Measured pressure

P_2 = Water vapor pressure

6

At this point the subjects were put through a two and one-half minute warm-up consisting of two minutes of treadmill running at 6 mph with 0 incline followed by ten push-ups and ten squats. The warm-up served to increase the heart rate to approximately 120 beats /min and to prepare the muscle group for action. The next step was the one minute performance. The subject was again seated on the apparatus and the tension was set at from 120 - 130% of that used in the VO_2 max test. Variation in tension occurred as a result of slipping when the bicycle was stopped after the setting had been made.

A maximal performance was encouraged by relating time left at five second intervals and by verbally prodding the subjects. (Ubrick and Burke 1957)

The expired volume of air during this one minute was collected in bag 1. At the end of the one minute, air flow was directed into bag 2 at the instant that bag 1 was closed. As each bag was filled air was directed into the next one in the series (fig. 7). This was continued until the heart rate returned to within five beats of the resting rate. At this point gas collection ceased and the subject was permitted to leave. Recovery time was recorded in minutes. As in the VO_2 max test all volumes were measured, temperature and pressure were recorded and percentage differences in oxygen were determined.

Treatment of data:

The data were collected on data collection sheets as shown on pages 51 and 52, Appendix C. All volumes were corrected to STPD and recorded on page 38 (Table 6) of Appendix A. Values for oxygen consumption were expressed in terms of mls/kg of body weight (Åstrand). The t-test for paired samples and Spearman's rank correlation were employed in the statistical analysis of the data. (Appendix B, p. 41). In the case of significant correlations a line of best fit was graphed by means of linear regression equations.

Fig. 8. Low Resistance Gas Mask

Chapter 3

RESULTS - DISCUSSIONS

Results:

Table 2. Physical characteristics of the subjects.

Subject	Age	Height (cm.)	Weight (kg)	% body fat
1	15	177.17	65.68	3.43
2	16	179.07	71.14	4.36
3	17	179.07	64.55	2.73
4	21	175.26	72.73	2.74
5	25	184.02	98.41	6.47
6	24	180.34	76.36	4.92
7	22	176.53	68.64	4.36
8	22	184.02	87.27	5.48
9	20	177.80	75.45	6.32
10	21	180.34	80.91	5.72
11	23	165.74	62.84	3.80
12	22	177.80	77.27	4.64
13	23	168.91	61.36	3.34
14	24	152.40	62.27	5.91
15	22	175.26	66.36	4.59
16	25	171.45	70.0	3.89
17	26	166.37	70.91	4.50
18	23	175.26	84.09	4.17
19	20	160.02	60.45	5.76
20	22	180.34	62.73	2.55

Table 3. Oxygen consumption and work done /kg of body weight during MMP and Maximum oxygen intake test.

One minute maximum Performance

Sub.	VO_2 during (ml/kg)	Oxygen debt (ml/kg)	Work done (Kgm/kg)	Aerobic work done (Kgm/kg)	Anaer. work done (Kgm/kg)	Aer. Effic. (Kgm/ml)	Anaer. Effic. (Kgm/ml)	VO_2 max (ml)	Physical Wor. Capacity (Kgm/kg)
1	45.9	28.9	27.27	15.9	11.37	.346	.393	64.4	22.3
2	45.16	76.3	35.85	14.69	21.16	.325	.277	82.8	26.94
3	42.32	67.2	39.68	15.98	23.70	.377	.353	74.7	28.20
4	36.19	59.6	36.11	14.92	21.19	.412	.356	59.5	24.53
5	29.00	56.6	27.79	15.09	12.70	.520	.224	43.7	22.74
6	38.31	-2.1	27.34	14.55	12.79	.379	*	46.9	17.81
7	43.22	81.1	37.35	20.32	17.03	.470	.209	46.9	22.05
8	39.46	52.8	30.27	16.29	13.98	.413	.265	42.1	17.38
9	37.04	44.3	31.05	19.04	12.01	.514	.271	34.0	17.48
10	31.63	70.9	27.47	11.27	16.20	.356	.228	46.3	16.49
11	35.70	112.4	41.30	12.81	28.49	.359	.253	56.5	20.27
12	36.70	84.5	38.23	16.14	22.09	.439	.261	48.5	21.33
13	36.30	78.6	41.40	17.93	23.57	.494	.299	44.1	21.78
14	40.82	101.6	40.56	15.81	25.75	.387	.252	57.8	22.38
15	41.51	86.4	31.22	16.19	15.03	.390	.174	52.6	20.52
16	37.26	86.5	41.65	11.46	30.19	.308	.348	64.1	19.72
17	36.77	75.4	37.83	16.55	21.28	.450	.282	41.3	18.59
18	36.40	69.7	32.59	15.62	16.97	.429	.243	56.6	24.29
18	34.62	74.0	31.77	17.65	14.12	.509	.191	31.6	16.11
20	43.76	97.9	38.34	23.02	15.32	.526	.156	55.5	29.19

Table 4. Correlation Coefficients for Relationship of Various Factors to a One Minute Maximum Performance

Factor	r	r required at .05 level
Physical work capacity	.304	-.377 r .377
Maximum oxygen intake	.298	-.377 r .377
VO_2 during MMP	.013	-.377 r .377
O_2 debt	.762*	-.377 r .377
Aerobic efficiency	-.065	-.388 r .388
Anaerobic efficiency	.329	-.388 r .388
Aerobic work done during MMP	.100	-.377 r .377
Anaerobic work done during MMP	.899*	-.377 r .377

* significant beyond the .01 level.

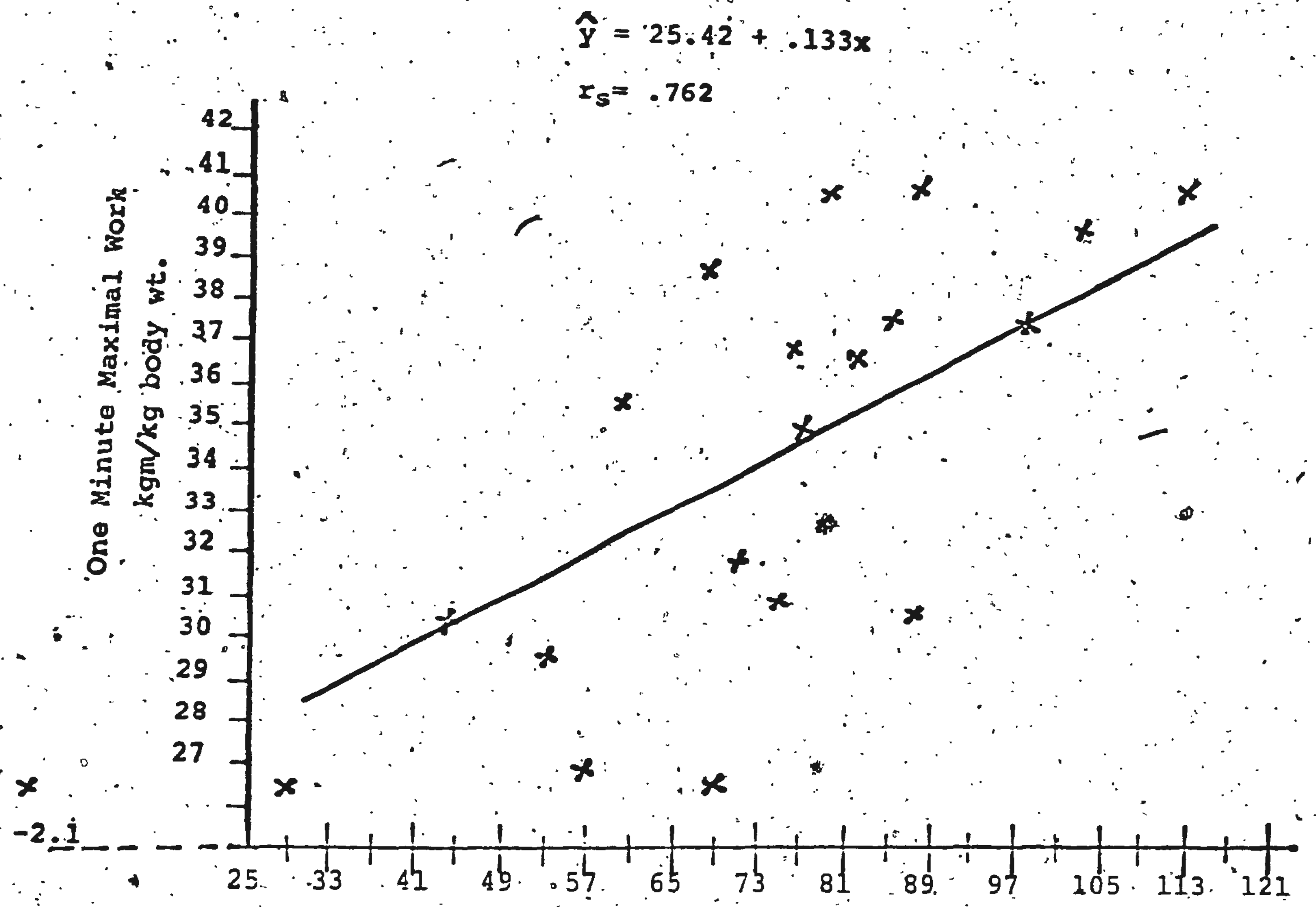

Figure 9 0_2 debt in ml/kg body wt.

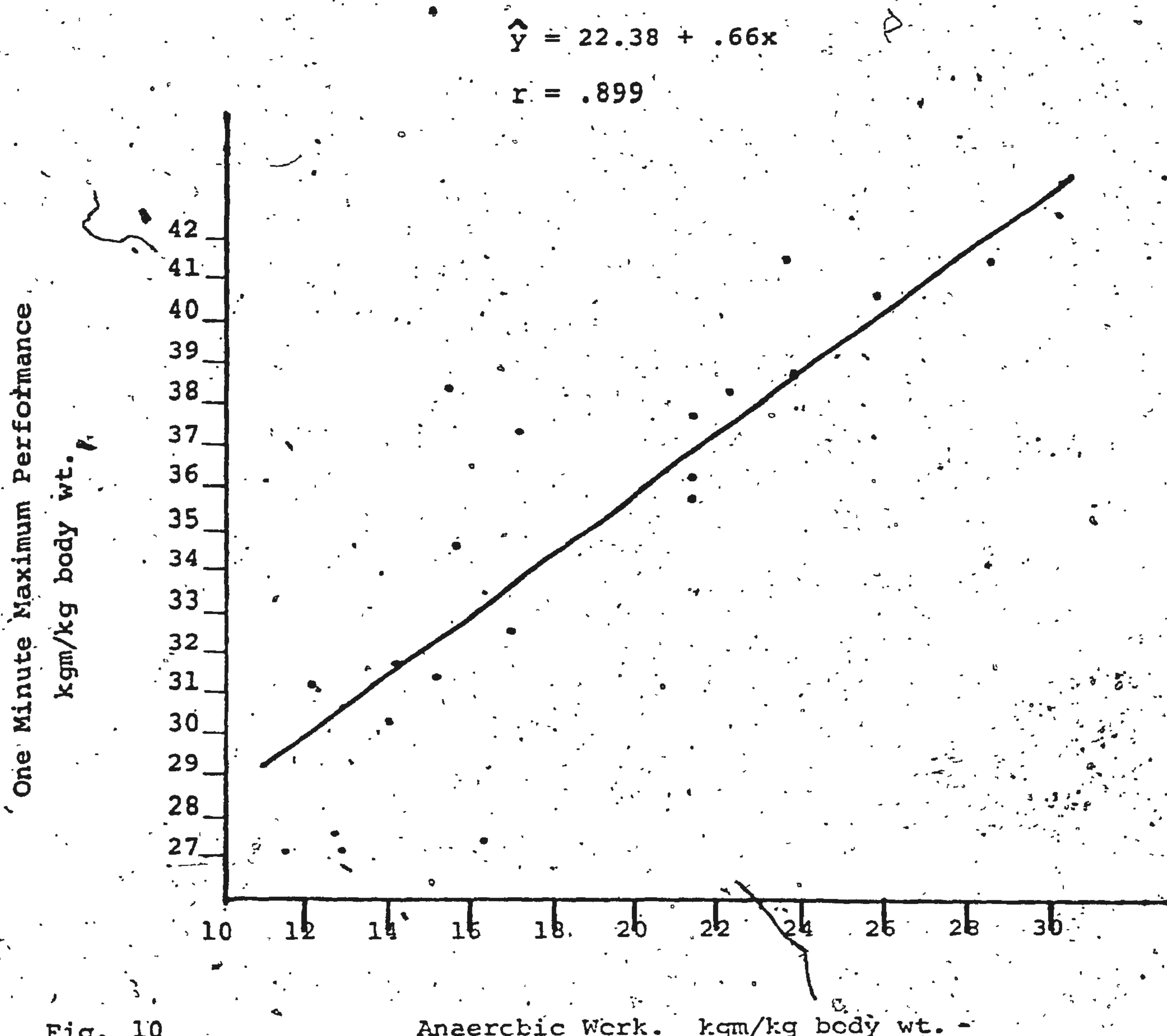
$\hat{y} = 22.38 + .66x$
$r = .899$
One Minute Maximum Performance
kgm/kg body wt.
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
10
12
14
16
18
20
22
24
26
28
30
Anaerobic Work. kgm/kg body wt.

Fig. 10

As indicated in table 4 most of the factors studied showed some relationship to the one minute maximum performance. However, the only two variables for which a statistically significant correlation was obtained were oxygen debt and anaerobic work. The correlation coefficient for oxygen debt to one minute maximum performance was .762 while that obtained between work done anaerobically and one minute maximum performance was .899. Both values were found to be significant beyond the .01 level. Linear regression lines were plotted for each on pages 25 and 26. respectively.

Although the coefficients for physical work capacity, maximum oxygen intake and anaerobic efficiency did not attain significance, it appeared that these variables were related to some degree to the one minute maximum performance.

In addition to the correlation studies t-tests were employed to determine the importance of certain components to the one minute maximum performance. The following inferences were made from the data recorded in table 5.

(1) Work done anaerobically during the one minute maximum performance was greater than the work done aerobically.

(2) Aerobic efficiency during the one minute maximum performance was significantly higher than anaerobic efficiency.

Discussion:

In view of the statistical analysis one might conclude that the only factor which was of any importance to the one minute maximum performance was the anaerobic component. As seen in the results the anaerobic component, with correlation coefficients of .762 for oxygen debt and .899 for work done anaerobically, was the major factor in determining one minute maximum performance. One must be careful, however, not to exclude the other factors. Though they did not attain significance statistically they are important to achieving a maximum one minute performance. For example, two subjects have equal skills and ability to build up oxygen debt but one has a slightly higher VO_2 during the one minute performance. Providing that efficiency is also equal the subject having the higher VO_2 would yield the greater amount of work /kg of body weight.

It appeared in the exercise physiology texts surveyed by the investigator that dominant role of the anaerobic component in intense work of short duration is supported. This study has provided additional testimony to the importance of the anaerobic component but in a maximum effort of one minute's duration.

As in the case of Henry's study (1954) in which total oxygen requirement was estimated for given performance, the oxygen debt incurred and the anaerobic work may be predicted for a given one minute performance from equations 1 and 2 respectively.

equation 1: $y = 25.42 + .133x$ where y = MMP
x = Oxygen debt

equation 2: $y = 22.38 + .66x$ where y = MMP
x = Anaerobic work

As seen in table 3, page 22, a value for oxygen debt of -2.1 was obtained by subject 6 and an anaerobic work value of 12.79 Kgm. This was an apparent contradiction since nothing is obtained for nothing. When the -2.1 value was dropped from the calculation of the correlation coefficient an r of .725 was obtained and the following equation formulated.

equation 3 $y = 23.61 + .156x$

where y = MMP

x = Oxygen debt.

Higher correlations for oxygen debt and anaerobic work might have been obtained if the determination of aerobic work, as described in limination 5 page 6, had been more accurate.

Selkurt (1971) stated that "oxygen cost does not rise linearly with velocity, but exponentially". The exponent of the oxygen cost rise with velocity increases usually ranges from 2 to 3. Although aerobic efficiency was found to be significantly greater than anaerobic efficiency a factor of 2 or 3 would have eliminated that difference, and conceivably resulted in anaerobic efficiency being greater than aerobic efficiency.

Morehouse and Miller (1971) reported that severe work was as little as 40% as efficient as aerobic work. In this study anaerobic work was found to be approximately 37% less efficient than aerobic work.

Chapter 4

SUMMARY - CONCLUSIONS

The purpose of this study was to determine the relative importance of the various components; aerobic metabolism, anaerobic metabolism and efficiency, to a one minute maximum performance (MMP). Although there have been many studies done with respect to these factors they had not previously been related to a one minute maximal effort.

The sample)N=20) was chosen on the basis of availability and activity level. Each subject was required to undergo (1) a maximum oxygen intake test and (2) a maximum one minute performance test. A resting volume for oxygen consumption per minute, a one minute maximum performance on the experimental apparatus and a recovery oxygen consumption comprised the MMP. The braking apparatus used in the study consisted of two bicycle ergometers so arranged as to be pedalled by both arms and legs simultaneously.

Statistical analysis employed Spearman's rank correlation to determine relationship of various factors to MMP and paired t-tests to establish the relative importance of the components of a MMP. The results obtained led to the following conclusions:

(1) The Anaerobic component was the most significant factor in determining MMP.

(a) Work done anaerobically was significantly greater (.01 level) than work done aerobically.

(b) Linear relationships existed between oxygen debt and MMP ($r = .762$), and between anaerobic work and MMP ($r = .899$).

(2) Efficiency was the second most important component with correlation coefficients of .329 and .065 respectively for the relationships of anaerobic and aerobic efficiency to MMP.

(3) The aerobic component was found to be of least importance in determining MMP. Coefficients of .100 and .013 were obtained for aerobic work and VO_2 during MMP.

Recommendations:

Within the limitations of the study the conclusions arrived at were considered to be valid. However, there are several ways in which future studies in this area might be improved.

Instead of using one test to establish one minute maximum performance the subjects could be required to undergo the test several times. The investigator noted that a few subjects could have maintained their highest speed for longer than 30 seconds while some faded during the final ten seconds of the test. Practice trials would ensure that a maximum performance was attained by allowing the investigator to shorten or lengthen the pacing time for each subject.

Monetary or other types of incentives could be employed to increase willingness to work. The practice trials might serve as encouragement to do better on successive performances.

Future studies might be enhanced by an investigation of heart rate adjusting during the MMP. The more rapidly the circulorespiratory system is able to adjust the greater will be the role of the aerobic component.

As has already been pointed out a study by Cunningham (1966) indicated a linear relationship between excess lactic acid and oxygen debt. It would be interesting to determine the relationship between excess lactic acid and MMP. On the basis of the substitution axion one might assume a high positive correlation between the two.

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APPENDICES

Appendix A

Table 6 Oxygen Consumption and Work Done per Total Body Weight

Sub	VO_2 Max (in L)	PWC (Kgm/min)	Resting VO_2 (L)	One Minute Performance VO_2 during	O_2	Work done
1	4.2315	1464.52	0.4427	3.0155	1.8960	1791.12
2	5.8872	1916.82	0.4151	3.2132	5.4266	2550.24
3	4.8187	1820.44	0.5801	2.7321	5.5131	2626.44
4	4.3267	1784.16	0.3490	2.6322	5.5131	2626.44
5	4.2993	2237.64	0.4153	2.8542	5.5810	2734.68
6	3.5815	1360.32	0.4213	2.9252	0.1611	2088.00
7	3.2177	1513.5	0.3749	2.9669	5.5689	2563.50
8	3.6706	1516.38	0.5158	3.4439	4.6044	2641.68
9	2.5665	1318.8	0.4312	2.7944	3.3411	2342.70
10	3.7494	1334.16	0.4747	2.5591	5.7356	2223.00
11	3.5485	1273.8	0.3583	2.2433	7.0659	2595.24
12	3.7442	1648.08	0.4413	2.8359	6.5295	2953.86
13	2.7051	1336.26	0.4047	2.2272	4.8212	1540.40
14	3.6006	1393.5	0.3322	2.5419	6.3267	2525.88
15	3.4917	1362.0	0.3699	2.7546	5.7321	2071.80
16	4.4902	1380.48	0.4015	2.6081	6.0560	2915.52
17	3.0895	1318.26	0.3878	2.6072	5.3437	2682.54
18	4.7578	2042.88	0.4425	3.0608	5.8610	2740.20
19	1.9104	973.74	0.3988	2.0929	4.4755	1920.38
20	3.4784	1831.2	0.3752	2.7451	6.1426	2406.04

Table 7: Conversion of Specific Gravity to Index of Obesity.

Specific Gravity	% Fat (20° C)
1.040	29.06
1.045	26.51
1.050	23.98
1.055	21.48
1.060	19.00
1.065	16.54
1.070	14.10
1.075	11.69
1.080	9.30
1.085	6.94
1.090	4.59
1.095	2.27
1.00	-0.04

Rathbun, E.N., and Pace, N: Studies on Body Composition Showing the Determination of Total Body Fat by Means of the Body's Specific Gravity. Journal of Biological Chemistry 158:667_676 May 1945.

Table 8: Pressure of Water Vapor in Millimeters of Mercury

°C	mm	°C	mm	°C	mm
0	4.6	21	18.7	30	31.8
5	6.5	22	19.8	35	42.2
10	29.2	23	21.1	40	55.3
15	12.8	24	22.4	50	92.5
16	13.6	25	23.8	60	149.4
17	14.5	26	25.2	70	233.7
18	15.5	27	26.7	80	355.1
19	16.5	28	28.3	90	525.8
20	17.5	29	30.0	100	760.0

Dull, Metcalfe & William, Modern Chemistry p. 676

Appendix B

Relationship of PWC to 1 minute maximal performance. Test statistic: Spearman's rank correlation coefficient

$$r_s = 1 - \frac{6\ Ed^2}{n(n^2-1)}$$

$-.337 \geq + \geq .337$ was required for statistical significance at the .05 level.

Ranks

PWC	EMP	d	d^2
8	20	-12	144
3	11	- 8	64
2	5	- 3	9
4	10	- 6	36
6	17	-11	121
16	19	- 3	9
9	9	-	-
18	16	2	4
17	15	2	4
19	18	1	1
13	3	10	100
11	7	4	16
10	2	8	64
7	4	3	9
12	14	- 2	4
14	1	13	169
15	8	7	49
5	12	- 7	49
20	13	7	49
1	6	- 5	25
			= 926

$r_s = .304$
(not significant at .05 level)

Relationship of VO_2 Max to 1 minute maximal performance Test Statistic: Spearman's rank correlation coefficient

$$r_s = 1 - \frac{6Ed^2}{n(n^2-1)}$$

$-.337 \geq r \geq .337$ required for significance at .05 level

Ranks

VO_2 Max	MMP	d	d^2
3	20	-17	289
1	11	-10	100
2	5	- 3	9
5	10	- 5	25
16	17	- 1	1
12.5	19	-6.5	42.25
12.5	9	3.5	12.25
17	16	1	1
19	15	4	16
14	18	-4	16
8	3	5	25
11	7	4	16
15	2	13	169
6	4	2	4
10	14	-4	16
4	1	3	9
18	8	10	100
7	12	-5	25
20	13	7	49
9	6	3	9
			=933.5

r_s= .298

(not statistically significant at .05 level)

Relationship of Oxygen debt to 1 minute maximal performance

Test statistic.

$$r_s = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$$

$-.337 \geq r \geq .337$ required for significance at .05 level

Ranks

Oxygen debt	MMP	d	d^2
19	20	-1	1
9	11	-2	4
14	5	9	81
15	10	5	25
16	17	-1	1
20	19	1	1
7	9	-2	4
17	16	1	1
18	15	3	9
12	18	-6	36
1	3	-2	4
6	7	-1	1
8	2	6	36
2	4	-2	4
5	14	-9	81
4	1	3	9
10	8	2	4
13	12	1	1
11	13	-2	4
3	6	-3	9

$r_s = .762$

Significant at .01 level ($\alpha \geq .534$)

8

Relationship of Aerobic component to 1 minute maximal performance.

Test statistic:

$$r_s = \frac{6Ed^2}{n(n^2-1)}$$

-.337 r .377 for significance at .05 level

Ranks Aerobic	MMP	d	d^2
1	20	-19	361
2	11	- 9	81
5	5	-	-
14	10	4	16
20	17	3	9
9	19	-10	100
4	9	- 5	25
8	16	- 8	64
11	15	- 4	16
19	18	1	1
17	3	14	196
13	7	6	36
16	2	14	196
7	4	3	9
6	14	- 8	64
10	1	9	81
12	8	4	16
15	12	3	9
18	13	5	25
3	6	- 3	9
			E = 1314

r = .013

(not significant)

Null Hypothesis, $H_0: u_0$ where u = aerobic work
u_0 = anaerobic work

Test Statistic : $t = \frac{\bar{d}}{s\, n}$; $s = \sqrt{\frac{E\ (A_1-\bar{A}_1)^2 + E(A_2-\bar{A}_2)^2}{n_1 + n_2 - 2}}$

A_1 Aerobic work kgm/min/kg	A_2 Anaerobic work kgm/min/kg	A_1-A_2	$A_1-\bar{A}_1$	$A_2-\bar{A}_2$
15.9	11.37	4.53	-0.16	-7.38
14.69	21.16	-6.47	-1.37	2.61
15.98	23.70	-7.72	-0.08	4.95
14.92	21.19	-6.17	-1.14	2.44
15.09	12.70	2.39	-0.97	-6.05
14.55	12.79	1.76	-1.51	-5.96
20.32	17.03	3.29	4.26	-1.72
16.29	13.98	2.31	0.23	-4.77
19.04	12.01	7.03	2.98	-6.74
11.27	16.20	-4.93	-4.79	-2.55
12.81	28.49	-15.68	-3.25	9.74
16.14	22.09	-5.95	0.08	3.34
17.93	23.57	-5.64	1.87	4.82
15.81	25.75	-9.94	-0.25	7.00
16.19	15.03	1.16	0.13	-3.72
11.46	30.19	-18.73	-4.60	11.44
16.55	21.28	-4.73	0.49	-2.53
15.62	16.97	-1.35	-0.44	-1.78
17.65	14.12	3.53	1.59	-4.63
22.02	15.32	7.70	5.96	-3.43
E 321.23	374.94	-53.61		
$\bar{A}$ 16.06	18.75	-2.68		

t = 2.723

Significant at .01 level (α = 2.539)

Efficiency = $\frac{\text{Out put}}{\text{Input}}$ $\frac{\text{kgm}}{\text{ml } O_2}$

Test Statistic: $t = \frac{\bar{d}}{s/\sqrt{n}}$; $s = \sqrt{\frac{E(E_1-\bar{E}_1)^2 \; E(E_2-\bar{E}_2)^2}{n_1 + n_2 - 2}}$

Where E_1 = Aerobic Efficiency
E_2 = Anaerobic Efficeincy

E_1	E_2	$E_1 - E_2$
.346	.393	-.047
.325	.277	.048
.377	.353	.024
.412	.356	.056
.520	.224	.296
.379	*	*
.470	.209	.261
.413	.265	.148
.514	.271	.243
.356	.228	.128
.359	.253	.106
.439	.261	.178
.494	.299	.195
.387	.253	.134
.390	.174	.216
.308	.349	-.041
.450	.282	.168
.429	.243	.186
.509	.191	.318
.526	.156	.370
E = 8.024	E = 5.037	Ed = 2.987
$\bar{E}_1$ .422	E_2 .265	D .157

t = 12.77

Significant at .01 level (= 2.552)

*Value of -2.1 indicated no oxygen debt, thus no efficiency value.

Relationship of Aerobic efficiency to 1 minute maximum performance.

$$r_s = 1 - \frac{6\,d^2}{n(n^2-1)}$$

Aer eff.	Anaer eff.	MMP	d_1	d_1^2	d_2	d_2^2
17	1	19	-2	4	-18	324
18	7	11	7	69	-4	16
14	3	5	9	81	-2	4
11	2	10	1	1	-8	64
2	15	17	-15	225	-2	4
6	16	9	-3	9	7	49
10	9	16	-6	36	-7	49
3	8	15	-12	144	-7	49
16	14	18	-2	4	-40	16
15	11.5	3	12	144	-8.5	72.25
8	10	7	1	1	3	9
5	5	2	3	9	3.0	9
13	11.5	4	9	81	7.5	56.25
12	18	14	-2	4	4	16
19	4	1	18	324	+3	9
7	6	8	-1	1	-2	4
9	13	12	-3	9	1	1
4	17	13	-9	81	4	16
1	19	6	-5	25	3	9
				1232		776.5

r for Aer. ≷ MMP = -.065

r for Anaer. vs MMP = .329

Rate of anaerobic ATV formation is of greatest importance in one minute maximum performance.

* Subject 6

rs =

Aer.	Anaer.	MMP	d_1	d_1^2	d_2	d_2^2
11	20	20	-9	81	0	-
16	9	11	5	25	-2	4
10	4	5	5	25	-1	1
15	8	10	5	25	-2	4
14	18	17	-3	9	1	1
17	17	19	-2	4	-2	4
2	10	9	-7	49	1	1
7	16	16	-9	81	0	-
3	19	15	-12	144	4	16
20	12	18	2	4	-6	36
18	2	3	2	225	1	1
9	6	7	8	4	1	1
4	5	2	-6	4	3	9
12	3	4	18	64	1	1
8	14	14	-2	36	0	-
19	1	1	1	324	0	-
6	7	8	-8	4	1	1
13	11	12	-5	1	1	1
5	15	13		64	2	4
1	13	6		25	6	49
				1198		134

$$r = 1 - \frac{6 \quad d^2}{N(n^2-1)} \qquad 1 - \frac{6 \quad d^2}{N(n^1-1)}$$

$$= 1 - \frac{6(1198)}{20(399)} \qquad 1 - \frac{6 \ (134)}{20(399)}$$

$$r = 1 - \frac{7188}{7980} \qquad 1 - \frac{804}{7980}$$

$$= 1 - .900 \qquad 1 - .1007$$

$$= .1 \qquad = .8993$$

$\hat{y} = \hat{B}_0 + \hat{B}_1 x$

$B_1 = \frac{SSxy}{SSx}$ $\qquad$ $B_0 = \hat{B}_1 \bar{x}$

$SSx = \Sigma(x_i - \bar{x})^2 = \Sigma x_i^2 - \frac{(x_i)^2}{n}$

y Work	x O_2 debt Anaer.	x_i^2	xy	y^2
27.27	28.9	835.21	788.103	743.6529
35.85	76.3	5821.69	2735.355	1285.2225
39.68	67.2	4515.84	2666.496	1574.5024
36.11	59.6	3552.16	2152.156	1303.9321
27.79	56.6	3203.56	1572.914	772.2841
27.34	-2.1	4.41	-57.414	747.4756
37.35	81.1	6577.21	3029.085	1395.0225
30.27	52.8	2787.84	1598.256	916.2729
31.05	44.3	1962.49	1375.515	964.1025
27.47	70.9	5026.81	1947.623	754.6009
41.30	112.4	12633.76	4442.12	1705.69
38.23	84.5	7140.25	3230.435	1461.5329
41.40	78.6	6177.96	3254.04	1713.96
40.56	101.6	10322.96	4120.896	1645.1136
31.22	86.4	7464.96	2697.408	974.6884
41.65	86.5	7482.25	3602.725	1734.7225
37.83	75.4	5685.16	2852.382	1431.1089
32.59	69.7	4858.09	2271.523	1062.1081
31.77	74.0	5476.00	2350.98	1009.3329
38.34	97.9	9584.41	3753.486	1464.9556
Σ 695.07	1402.6	111112.62	50441.498	24675.2813
m 34.7535	70.13			

Appendix C

Subject ____________ Barometric Pressure ____________

Test ____________ Temperature ____________

Resting VO_2/min

Vol. of expired air for 5 min. ____________

Percentage change in oxygen ____________

Vol. of oxygen consumed in 5 min. ____________

Vol. of oxygen consumed in 1 min. ____________

Resting heart rate ____________

1 Minute Maximal Performance

Tension setting Arms ________ Legs ________

Cycles during 1 min. Arms ________ Legs ________

Work done ____________

Vol. expired air collected during 1 min. ____________

Percentage change in oxygen ____________

Vol. of oxygen consumed during 1 min. ____________

Oxygen debt

Recovery time ____________

Recovered heart rate ____________

Vol. air expired during recovery ____________

Percentage change in oxygen ____________

Vol. of oxygen consumed during recovery ____________

N.B. All volumes converted to STPD before pxygen consumed was calculated.

Subject ______________ Atmospheric Pressure ______________

Test ______________ Room Temperature ______________

Skinfold Measurements

Abdominal ______________

Chest ______________

Triceps ______________

Specific gravity =

VO_2 Max:

Bag #	Heart Rate	Tension Arms	Setting Legs	Cycle/min Arms	Cycle/min Legs	Volume expired air	change in oxygen
1							
2							
3							

Physical Work Capacity .... ______________

Volume of expired air converted to STPD.......... ______________
(Maximum value only)

VO_2 Max...................................... ______________